Electrocoagulation feasibility study

## Assumptions

* It shall be assumed that the wastewater produced will only be due to domestic tasks. A table is given in the appendix listing what is commonly found in domestic wastewater.
* For the case of design we shall assume a high value for all pollutants as this will allow a margin for safety.
* Water quality required will be assumed to be potable (However a system could be built whereby electrocoagulation could be used for a secondary water supply to supply non-potable water).

## Water purity

Water purity can be split into 2 categories depending on the requirements of the space station.

1. Potable water (can be used for all domestic tasks).
2. Non-potable water ( can be used for everything except cooking and drinking)

## Process description

Electrocoagulation is a process of destabilising suspended, emulsified or dissolved contaminants in an aqueous medium by introduction of an electrical current. The electrical current provides the electromotive force causing the chemical reactions.

Several distinct electrochemical processes occur during the electrocoagulation process independently:

**Seeding** resulting from the anode reduction of metal ions that become new centres for larger, stable, insoluble complexes

**Emulsion breaking** resulting from oxygen and hydrogen ions reacting with emulsified substances and forming water insoluble material

**Halogen completing** - as the metal ions bind themselves to halogens resulting in formation of large insoluble complexes and isolating pesticides, herbicides, chlorinated PCBs, etc.

**Bleaching** by oxygen species produced in the reaction chamber and providing oxidisation of chemical substances and also reducing bio-hazards through oxidisation of bacteria, viruses, etc.

**Electron flooding** of the water affects the polarity of water, allowing colloidal materials to precipitate. The electrons create osmotic pressure rupturing cell walls of bacteria, cysts, and viruses.

**Oxidation and reduction** reactions are forced to their natural end point. Electrocoagulation can speed up the natural processes occurring in wet chemistry.

## Basic chemical process

The primary cathodic reaction is the reduction of hydrogen ions to hydrogen gas:

The principal anodic reaction is the release of metal ions into solution. Iron or aluminium is commonly used. The reaction is given by:

The wastewater passes through a chamber with the cathodes and anodes. The electrical current is introduced via parallel plates constructed of metals selected to optimise the removal process. The metal electrodes are used up during the process and slowly dissolve into the liquid medium. The metal ions tend to form metal oxides that electromechanically attract the destabilised contaminants.

# Process Flow Schematic



1. Feeding tank; 2. Reaction Chamber with electrodes; 3. Development Chamber

4. Sludge separation unit

# System Capabilities

1. Removes heavy metals;
2. Removes suspended and colloidal solids;
3. Destabilises oil and other emulsions;
4. Removes fats, oils and grease;
5. Removes complex organics; and
6. Destroys and removes bacteria, viruses and cysts.

# Feasibility

To effectively asses the applicability of electrocoagulation as a viable method for water purification, advantages and disadvantages have been listed:

Advantages:

1. Treats multiple impurities
2. Low power requirements
3. No chemical additions
4. Low maintenance
5. Can be used in batch reactor or CSTR set up
6. Minimal operator attention
7. Consistent and reliable results
8. pH is kept round 7 (neutral)

Disadvantages:

1. Cathodes and anodes need replacement
2. Suspended solids needs removal which can prove difficult

The effectiveness of the process will depend on wastewater type, pH, current density, type of metal electrodes, number of electrodes, size of electrodes, and configuration of metals. These variables affect the process time, kinetics, and removal efficiency.

In the case of the mars station a continuous stirred reactor would be more advantageous than a batch reactor. A continuous feed of wastewater allows the assumption that the reactor will be at (pseudo) steady-state conditions. A key advantage for such reactor systems is that their coagulant requirements are essentially fixed, a major advantage in terms of both design and operation4.

No concrete data could be sourced on removal rates as electrocoagulation is still modelled using mainly empirical data and heuristics and is highly variable upon the set up. However the following study based on an abattoir showed that typical removal rates achieved3:

- Phosphorus 70 – 90 %

- Oil & Grease 90 – 95 %

- TKN 50 – 65 %

- TSS 90 – 95 %

- COD 80 – 90 %

This was with 29 electrodes and a 10000 L/hr wastewater flowrate.

# Conclusion

Due to multiple contaminant treatment capability and high purity achievable by electrocoagulation it is strongly recommended that electrocoagulation be considered as a feasible method. However more research is required to see how many electrodes would be needed and how fast they would be used up. Electrodes would need replacement and thus may not be the best method to minimise weight on the resupply trips.

# Appendices

Table 1 Typical composition of untreated domestic wastewater1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | **Concentration** | | |
| **Contaminants** | **Unit** | **Weak** | **Medium** | **Strong** |
| Solids, total (TS) | mg L-1 | 350 | 720 | 1200 |
| Dissolved, total (TDS) | mg L-1 | 250 | 500 | 850 |
| Fixed | mg L-1 | 145 | 300 | 525 |
| Volatile | mg L-1 | 105 | 200 | 325 |
| Suspended solids (SS) | mg L-1 | 100 | 220 | 350 |
| Fixed | mg L-1 | 20 | 55 | 75 |
| Volatile | mg L-1 | 80 | 165 | 275 |
| Settleable solids | mg L-1 | 5 | 10 | 20 |
| BOD5 at 20 C | mg L-1 | 110 | 220 | 400 |
| Total organic carbon (TOC) | mg L-1 | 80 | 160 | 290 |
| Chemical oxygen demand (COD) | mg L-1 | 250 | 500 | 1000 |
| Nitrogen (total as N) | mg L-1 | 20 | 40 | 85 |
| Organic | mg L-1 | 8 | 15 | 35 |
| Free ammonia | mg L-1 | 12 | 25 | 50 |
| Nitrites | mg L-1 | 0 | 0 | 0 |
| Nitrates | mg L-1 | 0 | 0 | 0 |
| Phosphorus (total as P) | mg L-1 | 4 | 8 | 15 |
| Organic | mg L-1 | 1 | 3 | 5 |
| Inorganic | mg L-1 | 3 | 5 | 10 |
| Chlorides | mg L-1 | 30 | 50 | 100 |
| Sulfate | mg L-1 | 20 | 30 | 50 |
| Alkalinity (as CaCO3) | mg L-1 | 50 | 100 | 200 |
| Grease | mg L-1 | 50 | 100 | 150 |
| Total coliform | CFU 100 mL-1 | 106-107 | 107-108 | 108-109 |
| Volatile organic compounds (VOCs) | mg L-1 | <100 | 100-400 | >400 |

Potable water composition requirements2:

These guidelines include the following recommended limits on naturally occurring constituents that may have direct adverse health impact:

* Arsenic 10μg/l
* Barium 700μg/l
* Boron 2400μg/l
* Chromium 50μg/l
* Fluoride 1500μg/l
* Selenium 40μg/l
* Uranium 30μg/l

Organic species:

* Benzene 10μg/l
* Carbon tetrachloride 4μg/l
* 1,2-Dichlorobenzene 1000μg/l
* 1,4-Dichlorobenzene 300μg/l
* 1,2-Dichloroethane 30μg/l
* 1,2-Dichloroethene 50μg/l
* Dichloromethane 20μg/l
* Di(2-ethylhexyl)phthalate 8 μg/l
* 1,4-Dioxane 50μg/l
* Edetic acid 600μg/l
* Ethylbenzene 300 μg/l
* Hexachlorobutadiene 0.6 μg/l
* Nitrilotriacetic acid 200μg/l
* Pentachlorophenol 9μg/l
* Styrene 20μg/l
* Tetrachloroethene 40μg/l
* Toluene 700μg/l
* Trichloroethene 20μg/l
* Xylenes 500μg/l

# References

1. Metcalf and Eddy (1991) Wastewater Engineering. Treatment Disposal Reuse, G. Tchobanoglous and F.L. Burton (Eds.), 1820 pp. New York: McGraw-Hill.
2. Guidelines for Drinking-water Quality , Fourth Edition; World Health Organisation; 2011
3. Electrocoagulation Process for Wastewater Treatment, Meat & Livestock Australia Limited CAN 081678364 (MLA).
4. Peter K. Holt, W. Barton , C. Mitchell “The future for electrocoagulation as a localised water treatment technology” Chemosphere 59 (2005) 355–367